

Sound wave velocities of Fe₅Si at high-pressure and high-temperature conditions: Implications to lunar and planetary cores

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ABSTRACT

Elastic properties of Fe alloys are critical in constraining the compositions of planetary bodies by comparing to the planetary observations. The sound wave velocities and density of an Fe₅Si (9 wt% Si) alloy in body-centered cubic (bcc) structure were measured by combining an ultrasonic technique with synchrotron X-ray radiography at pressure (P) and temperature (T) conditions of 2.6–7.5 GPa and 300–1173 K, respectively. At room temperature, it is observed that adding Si to bcc-Fe increases the compressional wave velocity (v_p) but decreases the shear wave velocity (v_s). At high temperatures, we observed a pronounced effect of pressure on the v_s - T relations in the Fe₅Si alloy. The v_p -density (ρ) relationship of the Fe₅Si alloy is found to follow the Birch's law in the P - T range of this study, whereas the v_s - ρ relation exhibits complex behavior. Implications of these results to the lunar core and the Mercurian core are discussed. Our results imply that adding Si to a pure Fe lunar core would be invisible in terms of v_p , but exhibit a decreased v_s . Including Si in a sulfur-rich lunar core would display an increased v_p and a decreased ρ . Our density and sound wave velocity model provide lower and upper limit for a Si-bearing lunar core if 1–3 wt% Si content of enstatite chondrite is taken as compositional analog. A Si-rich (>9 wt%) Mercurian core model is derived to satisfy newly observed moment of inertia values by Messenger spacecraft.

Keywords: Fe-Si alloy, elastic wave velocity, lunar and planetary cores, high pressure, high temperature